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ANALYSIS BEHIND THE SLOPE STABILITY IN THE LIMESTONE QUARRY BLOK MLIWANG TIMUR PT. SEMEN INDONESIA (PERSERO) TBK. TUBAN, JAWA TIMUR

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ABSTRACT

Clay mining activities at PT. Semen Indonesia (Persero) Tbk uses a Surface Mining system with tiered or layered mining methods. The clay mining activity in east kuari mliwang has produced 4-6 layers from the lowest elevation which is +0 meters above sea level (masl), with the opening of an area of 27 hectares, from the results of mining that has been done. Each slope made must have safety factors that meet the standards set by the Ministry of Energy and Mineral Resources and the Indonesian National Standard (SNI) taking into account the efficiency of reserves that will be in the mine. The return analysis of slope stability was obtained based on the value of the safety factor of a slope using the Bishop Simplified method with the help of Rocscience Slide v6.0 software. Input data in the form of physical and mechanical properties obtained from laboratory testing. Determination of minimum safety factors using SNI 8460: 2017, ICS 91.010.01 for soil material, namely FK ≥ 1.5. The factors that affect slope stability at the study site are the physical and mechanical properties of the soil, the slope geometry, and the condition of the ground water table. The results of the calculation of slope stability safety factors at the study site have different results, for Block T-03, slopes with an overall height of 21 m, the overall slope angle of 27 ° has a FK value = 1.502. Block W-06, Slope with an overall height of 25 m, the overall slope angle of 27 ° has a FK value = 1.504. And Block Z-04, Slope with an overall height of 26 m, the overall slope angle of 30 ° has a FK value = 1.508. From the calculation results the average location of the study has a value of FK ≥ 1.5 which indicates the slope is in a stable condition.

Keywords: slope stability, safety factors, bishop simplified, rocscience slide

INTRODUCTION

Background

The stability of a slope in mining activities is influenced by geological conditions, the overall shape of the slope, groundwater conditions, external factors such as vibration due to blasting or operating mechanical devices and also from excavation techniques used in making slopes. A common way to express stability on the mining slopes is by safety factors. This factor is a comparison between the holding forces which keeps the slope stable, with the driving force causing a landslide.

Location selection at PT. Semen Indonesia (Persero) Tbk as a case study in this study was motivated by a clay mining process, with the potential for landslides on slopes to be very high. Clay mining activities at PT. Semen Indonesia (Persero) Tbk uses a Surface Mining system with tiered or layered mining methods. from the mining results that have been carried out there are several areas that cause landslides on the slopes. Therefore, a return analysis of slope stability is needed based on consideration of the conditions found in that location with the value of the safety factor that still meets the requirements.

Formulation of the problem

What are the types of avalanches that will occur in the East Mliwang Quarry, what are the factors that affect slope stability, and what is the safe geometry in the design of the slope of the mining deadline.

Scope of problem

The method used to analyze slope stability is the boundary equilibrium method, the Bishop Simplified method using the software Rocsience Slide v6.0 program. and the analysis used does not take into account earthquake factors and is limited to technical scope.

Research purposes

Identifying the types of avalanches that occur and will occur, obtain factors that affect slope stability related to safety factors at the research location and recommend geometry to obtain a combination of safe slopes in the design of the mining deadline slope based on technical considerations according to field conditions.

Benefits of research

Secure slope geometry for East Mliwang Clay Quarry is obtained and can be used as a consideration for safe slope geometry according to slope safety factors that meet the predetermined requirements.

LIBRARY REVIEW

Understanding of slopes and avalanches

Slopes are sloping fields that connect other fields that have different elevations. Slopes are formed naturally and with human assistance. Every type of slope, the possibility of landslides is always there. Landslides occur due to the driving force. Landslide is a downward displacement of a soil mass that occurs on the surface of a weak field (Braja, 2006). This landslide process will not stop before reaching a new equilibrium in different shapes and dimensions.

The stability of a slope is influenced by parameters such as groundwater conditions, overall slope shape and physical and mechanical properties of slope-forming materials such as cohesion, fill weight, internal friction angle.

Definition of Land

Soil is an accumulation of mineral particles that have no or weak bonds between particles, which are formed by weathering from rocks. Among the soil particles there is empty space called pores (void space) that contain water and / or air (Craig, 1989). According to Bieniawski (1973) Soil is a natural formation material that has a uniaxial compressive strength of less than 1 MPa while rocks are more than 1 MPa.

a. Clay Genes

Clay is formed from the sedimentation process. The process is the process of changing from volcanic rocks as origin rock into clay minerals. Clay is the result of disintegration, chemical weathering, especially the effect of H_2O and CO_2 assisted by microorganisms.

b. Physical Properties and Properties of Chemical Clay

The physical and chemical properties of East Mliwang kuari clay are as follows:

- Physical properties:

Color : Brownish yellow and blackish gray
Moisture content : 26.18% - 33.50%
Content weight : 1.8 - 2.1 gr / cm3 (17.66 kN / m3 - 20.601 kN / m3)

- Chemical properties:

Low Grade (Low Alumina)		High Grade (High Alumina)	
SiO_2	: 71.83%	SiO_2	: 55.19%
Al_2O_3	: 13.94%	Al_2O_3	: 22.82%
Fe_2O_3	: 5.17%	Fe_2O_3	: 6.07%
CaO	: 1.08%	CaO	: 0.60%
MgO	: 0.55%	MgO	: 2.23%

From the data above shows that clay in the Mliwang Timur area is feasible and meets the requirements as raw material for cement, for SiO_2> 40% and Al_2O_3> 10%. In accordance with the provisions set by PT. Semen Indonesia (Persero) that Al_2O_3> 15% including high grade (high alumina) and Al_2O_3 <15% including low grade quality (low alumina), then East Mliwang quarry is high grade (high alumina) clay.

Basic Mechanism of Landslides on Slopes

a. Deep Swipe Angle, Cohesion and Fill Weight

Material properties that are relevant to slope stability problems are deep friction angles, cohesion, and weights of soil or rock masses. The definition of deep friction angles and cohesion will be explained in Figure 1. The figure explains simply about rock samples that have a field of continuity and then work on shear stresses and normal stresses. so that it will cause the rock to crack in the area of continuity and experience a shift. The normal voltage relationship can be stated as follows:

$$\tau = c + \sigma \tan \phi \qquad (1)$$

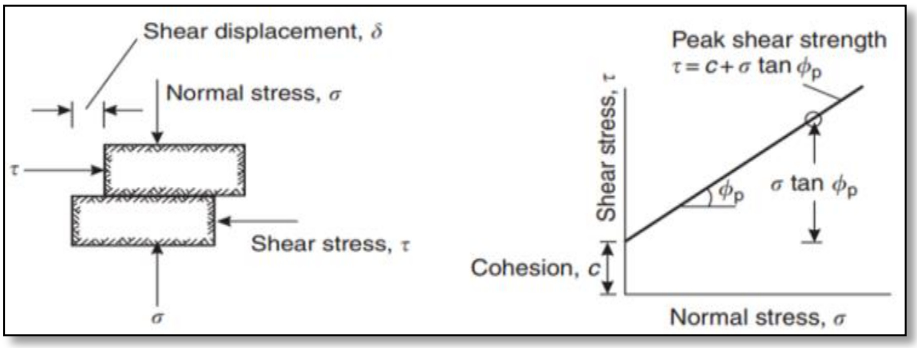

Fig.1. Graph of the Relationship of Normal Voltage - Slide Voltage

b. Effect of Vibration on Slopes

The effect of force from vibrations originating from sources near the slopes can also affect slope stability. This vibration, for example, is caused by heavy equipment activities, earthquakes, vehicle traffic around the slopes, and blasting activities. The force generated from this vibration is called seismic force and is expressed in the value of a seismic coefficient.

c. Slope Safety Factors

According to Lee W. Abramson et al (2002) For slope design, FK (non-negative) required is usually in the range of 1.25 to 1.5. A higher factor is needed if there is a greater risk of loss of life or uncertainty about the design parameters.

Table 1. Value of safety factors for soil slope (SNI: 8460: 2017, ICS 91.010.01)

Costs and consequences of slope failure	The level of uncertainty in the analysis conditions	
	Low[a]	High[b]
Repair costs are worth the additional cost of designing more conservative slopes	1,25	15
Repair costs are greater than the additional costs of designing more conservative slopes	1,5	2,0 or more
[a]The level of uncertainty in the analysis conditions is categorized as low, if geological conditions can be understood, soil conditions are uniform, soil investigations are consistent, complete and logical to conditions in the field. [b]The level of uncertainty in the analysis conditions is categorized as high, if geological conditions are very complex, soil conditions vary, and soil investigations are consistent and unreliable.		

Factors Affecting Slope Stability

a. Slope Geometry

Which affects the slope stability design are: • Orientation (strike) and slope (dip) slope • Bench height (bench angel) (each level). • Bench width (bench width).

b. Soil Physical and Mechanical Properties

- Content weight (γ) Content weight is the weight of the soil per unit volume (Braja, 2006). Content weight is used to calculate the load on the surface of the landslide field.
- Ground shear strength (ɷ) Soil shear strength is internal resistance per unit area when the soil can resist collapse and shift along the fields inside (Braja, 2006). The parameters of soil shear strength can be obtained from laboratory testing, one of which is direct shear strength testing.
- Cohesion (c) Cohesion is the attraction between particles in soil or rock, expressed in units of weight per unit area. Soil or rock cohesion will be even greater if the shear strength is greater. Landslide Classification In general, landslides in the open pit are classified into 4 types of landslides (Kliche. 1999), namely:
  a. Plane Failure
  b. Vedge Failure
  c. Circular Failure
  d. Toppling Failure

Bishop Simplified Method

The Bishop method is the method introduced by A.W. Bishop uses a cut method where the forces acting on each piece are shown as in Figure 2. The Bishop method is used to analyze the slip surface in the form of a circle. In this method, it is assumed that the total normal forces are / work at the center of the piece and can be determined by describing the forces on the pieces vertically or normally. Balance requirements are used on the pieces that make up the slope. The Bishop method assumes that the forces acting on the slices have a resultant zero in the vertical direction (Bishop, 1955). For slopes divided into n slices. In general there are three kinds of assumptions that can be made:

a. Assumptions about normal voltage distribution along the slip surface
b. Assumptions about the inclination of forces between pieces
c. Assuming the position of the resultant lines of forces between pieces.

In most analysis methods, normal forces are assumed to work at the center of the base of each piece, because the pieces are thin. This is applied to a number of assumptions. The Bishop method uses assumptions as much as (2n - 1).

Taking into account the overall balance of the force, the Bishop method for the FK safety factor formula is obtained as follows:

$$FK = \frac{[c'l+(P-ul)\tan \emptyset'}{W \sin \alpha} \quad \text{.......} \quad (2)$$

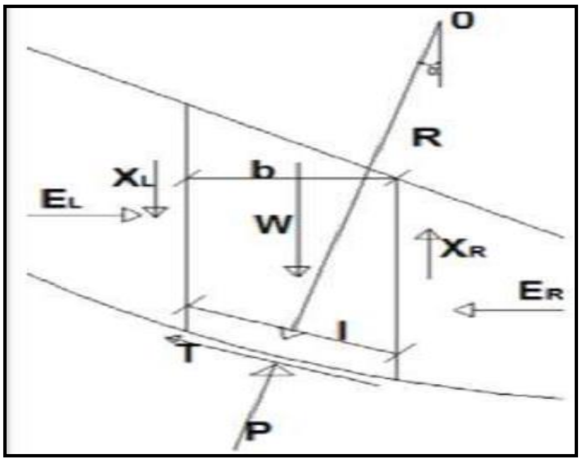

Fig. 2. The forces acting on a piece

Rocscience Slide

Rocsience Slide is one of the geotechnical software that specializes as a slope stability calculation software. Basically the Rocscience Slide is one of the programs in the Rocscience geotechnical calculation package consisting of Swedge, Roclab, Phase2, RocPlane, Unwedge, anRocData. In general, the slope stability analysis step with Rocscience Slide is modeling, identification of calculation methods and parameters, identification of materials, determination of slip fields, running / calculation, and interpretation of FoS values with Slide complement software named Slide Interpret.

Slope stability analysis has a fairly high level of complexity and has many variables. In addition, the accuracy of slope stability is also strongly influenced by the accuracy of the parameters entered in relation to the actual conditions. Calculation of detail and the element of uncertainty is quite large (represented by probability parameters) so that if the calculation is done manually it will take quite a long time and the accuracy is not optimal.

RESEARCH METHODS AND DATA

Representative data representing field conditions can be used to analyze the stability of a slope. Data as a basis for the analysis were obtained from investigations at the site of research and testing in the laboratory.

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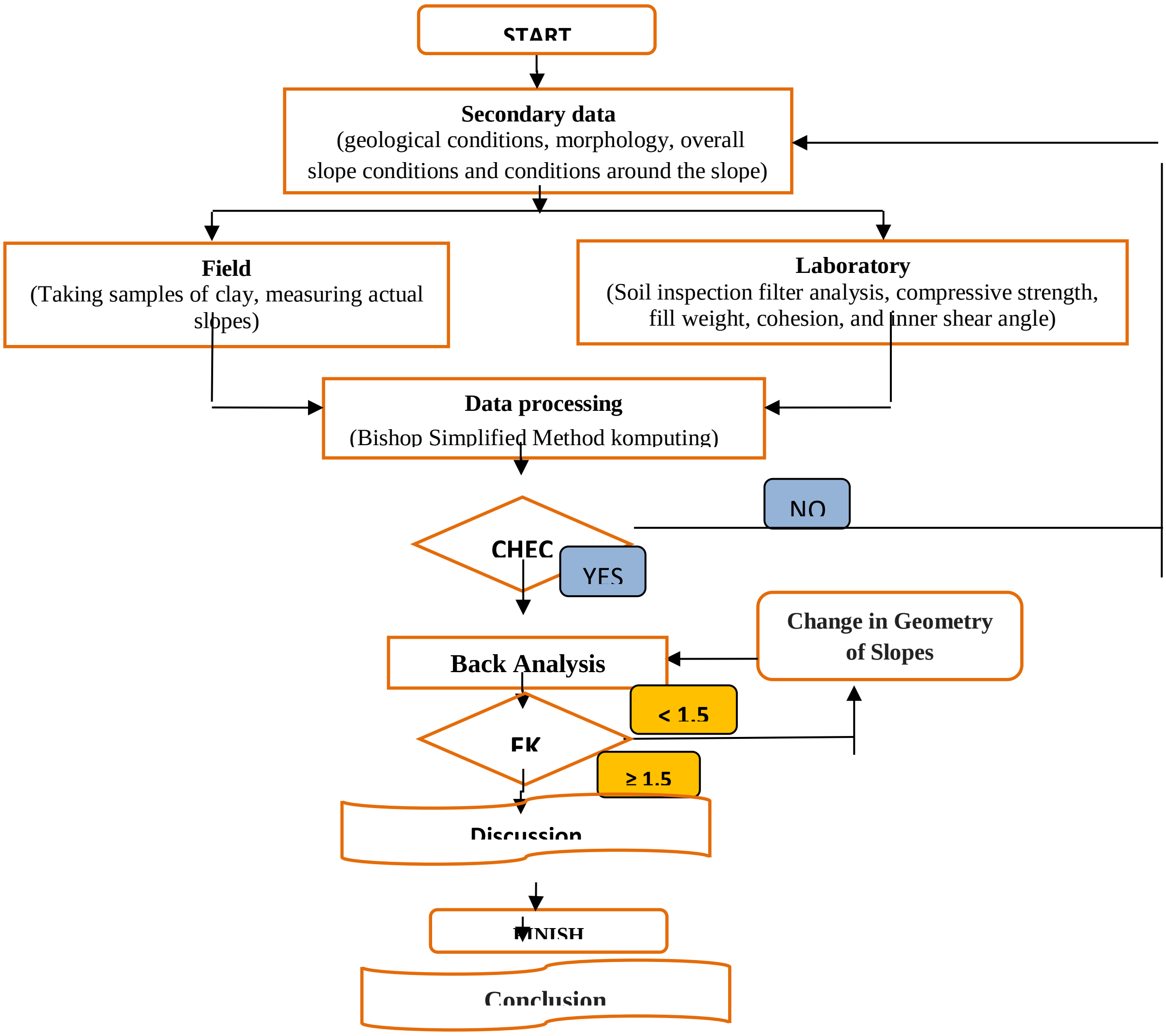

Fig. 3. Research Flow Chart

Research Location Investigation

a. Research Sites

The study was carried out on the mining slopes of the East Mliwang Quarry area located at coordinates 6o50'37 "LS - 6o51'45" LS and 111o55'57 "BT - 111o56'45" BT.

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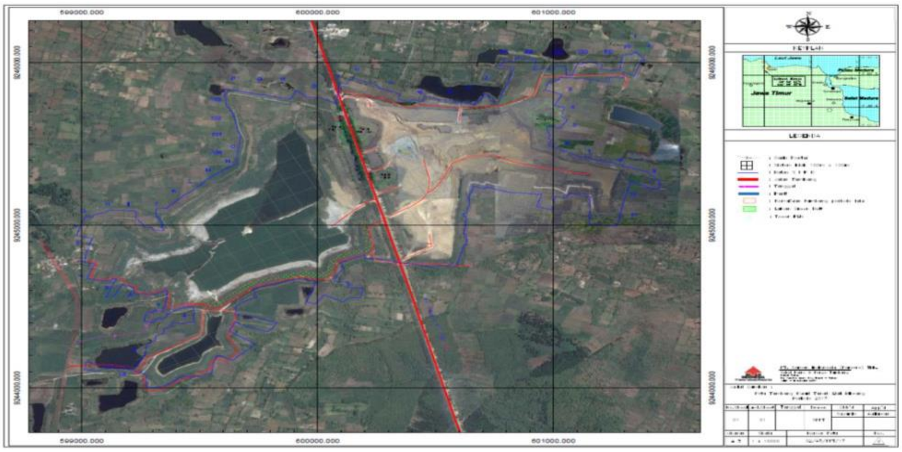

Fig. 4. Map of East Mliwang Clay Quarry Mine Drone

b. Physical and Mechanical Test Results in the Laboratory

Table 2. Resume Physical and Mechanical Properties of Low Alumina Points

Parameter	Example Code		
	T - 03	W - 06	Z - 04
Material Description	Clay *Low Alumina*		
Material Depth (m)	0-4 m		
Fill Weight, kN / m3	20,39	17,39	17,64
Water content, %	28,56	27,75	32,93
Specific gravity	2,4	2,66	2,58
Cohesion, kN / m2	31,15	25,71	33,43
Deep Swipe Angle, deg.	20,54	21,27	15,8
Free Press Strength, kg / cm2	0,658	0,539	0,712

Table 3. Resume Physical and Mechanical Properties of High Alumina Points

Parameter	Example Code		
	T - 03	W - 06	Z - 04
Material Description	Clay *High Alumina*		
Material Depth (m)	> 4 m		
Fill Weight, kN / m3	16,64	17,64	17,33
Water content, %	43,78	40,17	37,65
Specific gravity	2,66	2,5	2,75
Cohesion, kN / m2	33,43	28,28	46,29
Deep Swipe Angle, deg.	14,25	17,08	23,33
Free Press Strength, kg / cm2	0,691	0,596	0,938

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ANALYSIS AND DISCUSSION

Slope stability analysis

Mining activities at the research sites themselves have standard slope geometry parameters in accordance with the stipulated Amdal regulations. The reverse analysis of this study was carried out with slope safety factors, namely FK ≥ 1.5, to prevent avalanches that had occurred previously at the Block T-03 point location and at locations prone to landslides. Clay material mined at the study site was divided into a layer of low alumina at a depth of 0-4 m and a layer of high alumina at a depth of> 4 m.

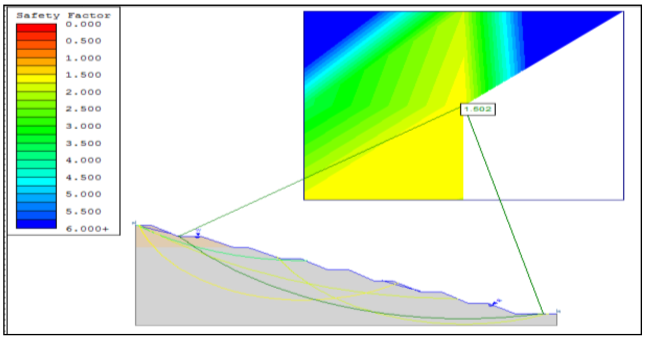

Fig. 5. Results of Calculation of the Safety Factors for the Overall Slope Design of Block T-03 Clay with Software Slide v6.0

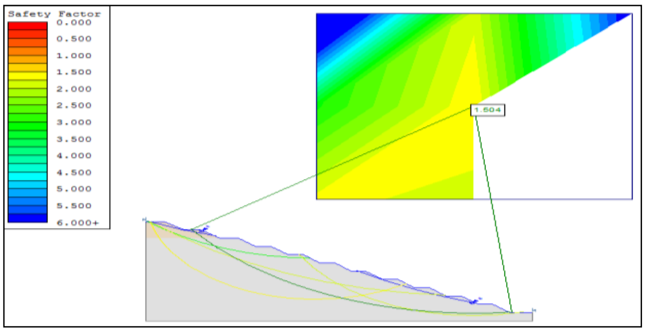

Fig. 6. Results of Calculation of the Safety Factors for the Overall Slope Design of Block W-06 Clay with Software Slide v6.0

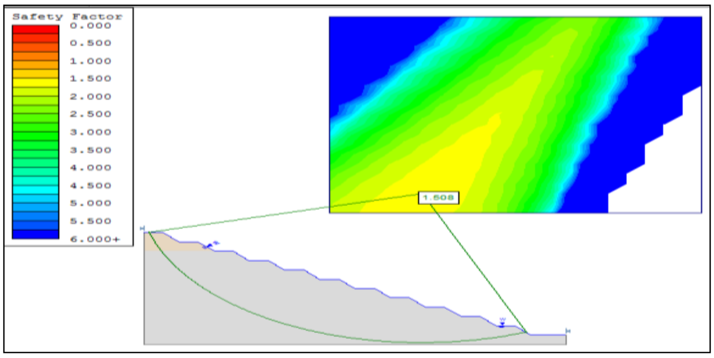

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Fig. 7. Results of Calculation of the Safety Factors for the Overall Slope Design of Block Z-04 Clay with Software Slide v6.0

Table 4. Recommended Selected Mining Slopes

POINT OF EXAMPLE	OVERALL HIGH (m)	SINGEL HIGH (m)	WIDE BANK WIDHT (m)	OVERALL CORNER (°)	SINGEL CORNER (°)	SAFETY FACTORS SATURATED
T - 03	21	2	4.5	27	42	1.502
W - 06	25	2	4.5	27	42	1.504
Z - 04	26	2	4	34	48	1.508

CONCLUSIONS AND SUGGESTIONS

Conclusion

- From the analysis of slope geometry with the Rocsience Slide software and seen in the actual condition of avalanches against the literature review. So the type of avalanches that occur in the research location can be concluded is a landslide.
- The results of the calculation of safety factors and analysis of slope stability at the study site are strongly influenced by the type of clay material. The value of cohesion and safety factors at each point of the research location have different values. This is due to differences in precipitation of clay and the difference in aluminum content in each layer of clay, namely low alumina and high alumina.
  Clay with high alumina content has a higher FK than low alumina, so that the design of the slope will be more varied and more upright angle.
- After geotechnical modeling is carried out in all research locations and in accordance with the standard slope geometry parameters resulting from the Environmental Management Plan (RPL) / AMDAL of PT. Semen Indonesia 2 meter high slope, Kepmen SDM RI 2018 Article 2b paragraph 4 concerning mine geotechnical and Article 6b paragraph 2 point (xv) concerning mining slope and Kepmen 555 1995 regulation article 241 no.2, namely bench height for work carried out on layers containing sand, clay, gravel, and other loose materials must: (point b) should not be more than 6 m if done mechanically. The maximum range of digging height according to the classification of tools used by the company is 9,46 meters, so the optimum geometry can be given as a recommendation.

a. Mining is done by a block system:

- Block T-03, slope with overall height of 21 m, overall slope angle of 27 ° has FK value = 1.502, single slope height of low alumina 2 m, and 42 ° angle has FK value = 4.073 and single slope height of high alumina 2 m, and the angle of 42 ° has FK = 4,845.
- Block W-06, Slope with overall height of 25 m, overall slope angle of 27 ° has FK value = 1.504, single slope height of low alumina 2 m, and angle of 42 ° has FK

value = 5.798 and single slope height of high alumina 2 m, and the 42 ° angle has FK = 6.092

- Block Z-04, Slope with overall height of 26 m, overall slope angle of 30 ° has FK value = 1.508, single slope height of low alumina 2 m, and angle of 48 ° has FK value = 5.819 and single slope height of high alumina 2 m, and an angle of 48 ° has FK = 8.207

Suggestion

- The results of recommendations in this study can be used as a reference for companies in slope design to prevent landslides, especially in areas prone to landslides that occur at the point of block T-03, with recommendations for overall slope safety factor FK ≥ 1.5.
- It is necessary to observe groundwater levels through water well data or drill data, so that slope analysis better reflects actual conditions.
- The final slope design is used for saturated groundwater conditions in the rainy season and the groundwater level is not saturated during the dry season. So, to prevent the slopes from becoming saturated with water, tresching around the mine area needs to be made and water flowed to the nearest river from the mining area.

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